CHAPTER 11
PRIMARY TREATMENT

11-1. Function.

The purpose of primary treatment is to remove solids which are not removed during preliminary treatment (chap 10). Processes which can be used to provide primary treatment include the following: 1) primary sedimentation, also called clarification; 2) microscreens; and 3) Imhoff tanks. In most facilities, primary treatment is used as a preliminary step ahead of biological treatment.

11-2. Primary sedimentation.

Sedimentation tanks are designed to operate continuously. They are usually rectangular or circular and have hoppers for sludge collection. Most sedimentation tanks are constructed with gently sloped bottoms and have sludge hoppers with relatively steep sides. Non—mechanized settling tanks are used only in very small installations; the sludge moves to hoppers by gravity, where it is removed.

a. Function. Primary sedimentation tanks may provide the principal degree of wastewater treatment, or may be used as a preliminary step in further treatment of the wastewater. When used as the only means of treatment (no longer authorized in U.S. and Trust territories), these tanks provide for removal of settleable solids and much of the floating material. When used as a preliminary step to biological treatment, their function is to reduce the load on the biological treatment units. Efficiently designed and operated primary sedimentation tanks should remove 50 to 65 percent of the suspended solids and 25 to 40 percent of the biochemical oxygen demand.

b. Design parameters. The tanks will be designed for the average daily flow or daily flow equivalent to the peak hourly flow that requires the largest surface area. Table 11—1 shall be used to select the correct surface loading rate. All tank piping, channels, inlets, outlets and weirs will be designed to accommodate peak flows. Use 3.0 times the average hourly flow if specific peak flows are not documented.

Table 11-1. Surface loading rates for primary settling tanks.

Plant Design Flow mgd	Surface Loading Rate,* gpd/sq ft	
	Average Flow	Peak Flow
0- 0.01	300	500
0.01- 0.10	500	800
0.10- 1.00	600	1,000
1.00-10.0	800	1,200
above 10.0	1,000	1,200

* These rates must be based on the effective areas (figs 11-1 and 11-2).

Each tank will be sized, as a maximum, for 67 percent of the plant design flow (facility designs will normally include two tanks). At treatment plants with less than 0.1 million gallons per day treatment capacity, one unit is acceptable when an equalization tank or holding basin is constructed with adequate volume to dampen out peak inflow rates.

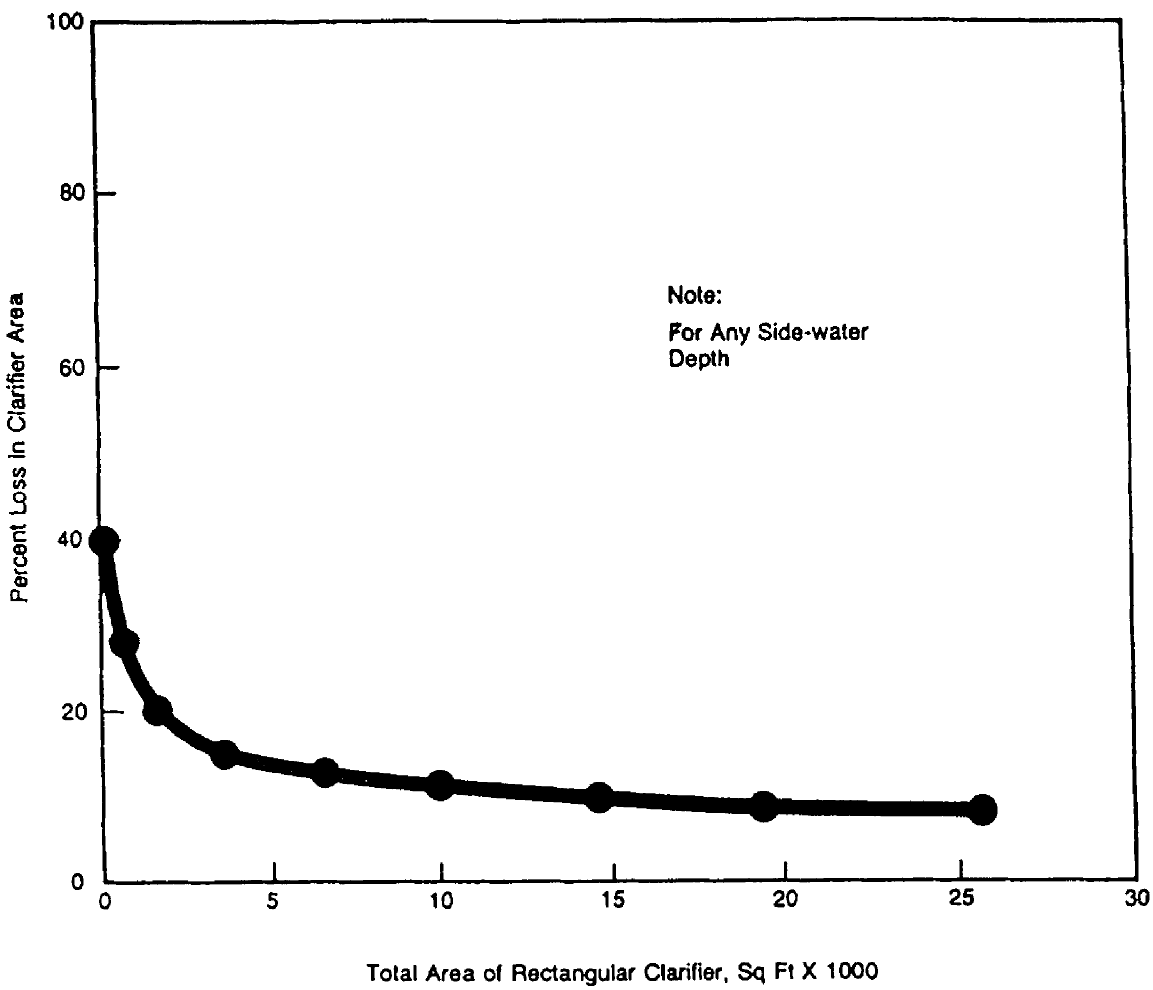

Figure 11-1. Effective Surface area adjustments for inlet—outlet losses in rectangular clarifiers, L:W = 4.

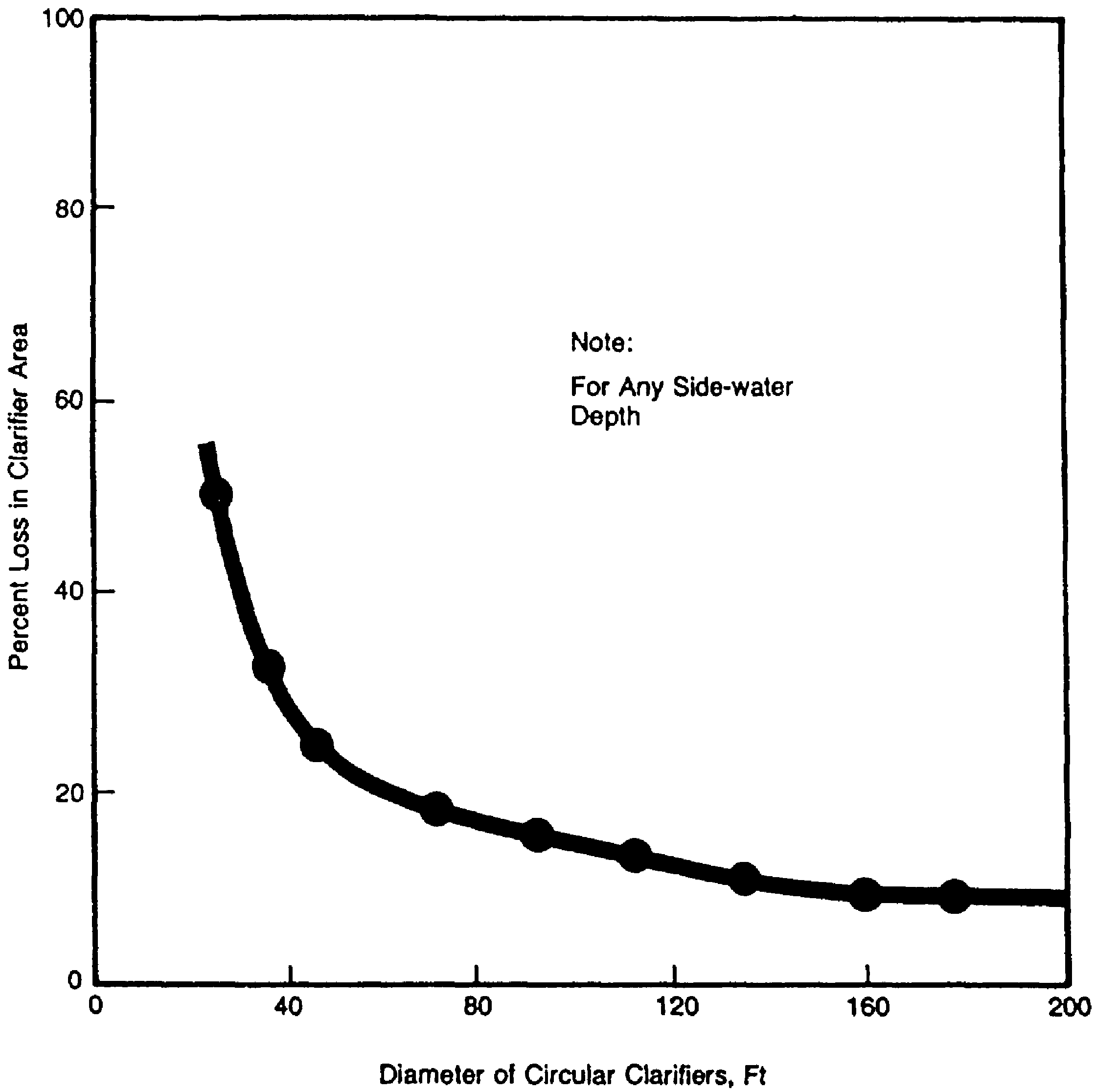

Figure 11-2. Effective surface area adjustments for inlet—outlet losses in circular clarifiers.

Sedimentation tanks designed for chemical addition applications will utilize the overflow rates stipulated in table 11-4 regardless of the design plant size.

(1) **Design considerations**.

(a) Detention period. Detention time is commonly specified as 2.5 hours for primary tanks serving all types of plants except when preceding an activated sludge system, where detention time is specified as 1.5 hours. Selection of optimum detention time will depend on the tank depth and the overflow rate. For those military installations where the contributing population is largely non-resident, the detention period to be used in design of primary settling tanks is 2 hours, based on the average hourly rate for the 8-hour period when the maximum number of personnel will be contributing to sewage flow.

(b) Weir rate. The overflow loading on weirs will not exceed 5,000 gallons per day per lineal foot for plants designed for less than 0.1 million gallons per day, or 10,000 gallons per day per lineal foot for plants designed between 0.1 and 1.0 million gallons per day. Weir loading for plants designed for flows of more than 1.0 million gallons per day may be higher, but must not exceed 12,000 gallons per day per lineal foot. When pumping is required, the pump capacity will be related to tank design to avoid excessive weir loadings.

11-3. Sedimentation design features.

Inlets to a settling tank will be designed to dissipate the inlet velocity, to distribute the flow uniformly, and to prevent short circuiting. The inlet and outlet channels will be designed for a minimum velocity of 2 feet per second at the average flow rate and will have corners filleted to prevent deposition and collection of solids. The guidelines shown in table 11—2 will be used for designing the depths of settling tanks:

Table 11–2. Settling tank depths.

Clarifier Length or Diameter ft	Minimum Liquid Depth ft	Sludge Blanket Depth ft	Minimum Total Depth ft
Rectangular up to 50 ft length	6	2	8
50–100	6–7	2	8–9
100–150	7–8	3	10–11
150–200	8–9	4	12–13
Circular up to 50 ft diameter	7	2	9
50–100	7–8	2	9
100–150	8–9	3	11–12
150–200	9–10	4	13–14

Limit the use of circular clarifiers to applications greater than 25 feet in diameter. Where space permits, at least two units will be provided except as modified by paragraph 11-2**b**.

a. Rectangular tanks. The minimum length of flow from inlet to outlet of a rectangular tank will be 10 feet in order to prevent short circuiting of flow in the tank. In existing installations, tank length-to-width ratio varies between 3:1 and 5:1. Tanks will be designed with a minimum depth of 7 feet except final tanks in activated sludge plants, which will be designed with a 9-foot minimum depth. Figure 11-3 illustrates a typical rectangular sedimentation tank.

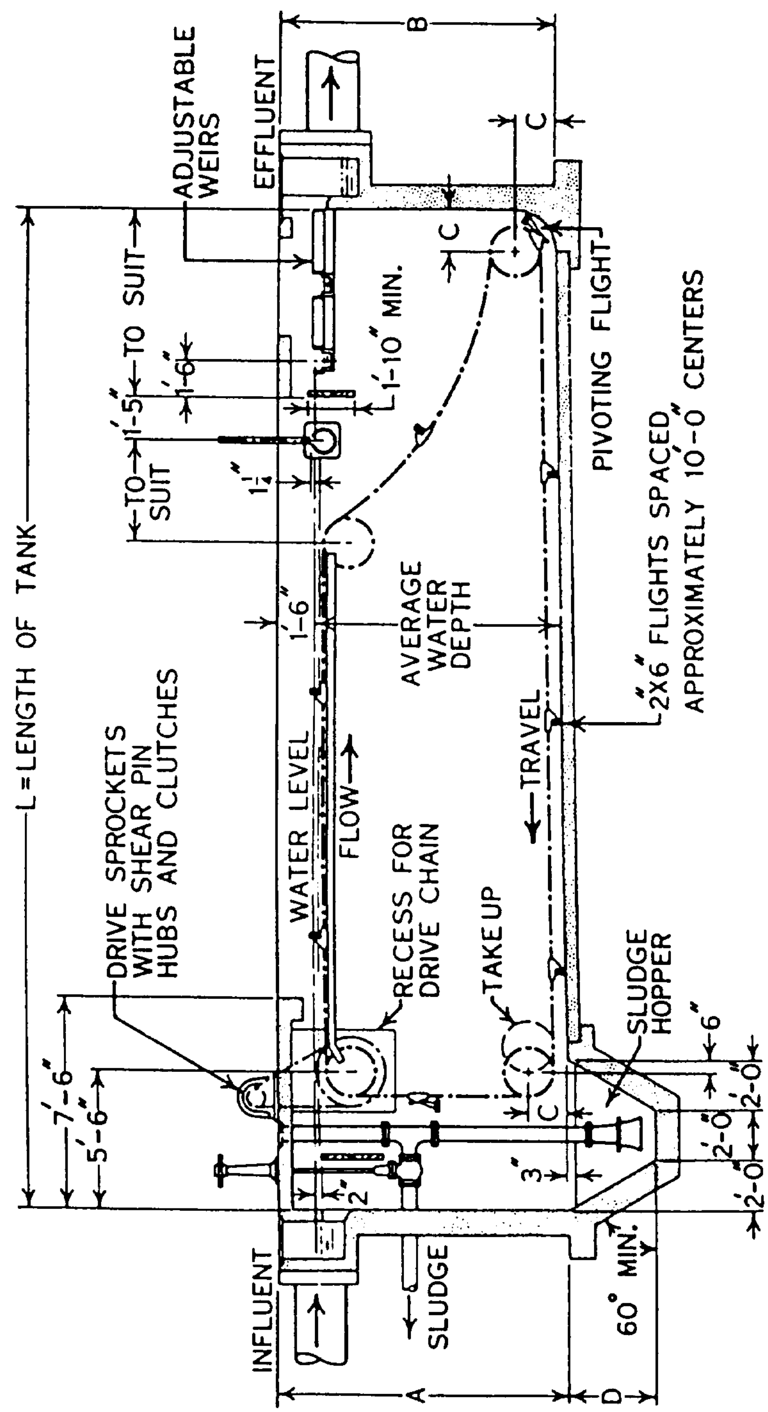

Figure 11–3. Typical rectangular primary sedimentation tank.

(1) **Inlets and outlets**. Inlets to rectangular tanks will be designed so as to prevent channeling of wastewater in the tank. Submerged ports, uniformly spaced in the inlet channel, are an effective means of securing distribution without deposition or channeling. Outlet overflow weirs used in rectangular tanks will be of the adjustable type, and serrated weirs are preferred over straight ones. Overflow weirs will be used in most cases.

(2) **Collection and removal of scum and sludge**. Means for the collection and removal of scum and sludge are required for all settling tanks. The removal of scum from the tank will take place immediately ahead of the outlet weirs, and the equipment may be automatic or manual in operation. Provisions will be made so that the scum may be discharged to a separate well or sump so that it can be either sent to the digester or disposed of separately. Rectangular tanks will be provided with scum troughs with the crest about 1 inch above maximum water surface elevation. For small installations (less than 1.0 million gallons per day), hand-tilt troughs consisting of a horizontal, slotted pipe that can be rotated by a lever or screw will be used. Proven mechanical scum removal devices such as chain-and-flight types may be used for larger installations. To minimize the accumulation of sludge film on the sides of the sludge hoppers, a side slope of at least 1½ vertical to 1 horizontal will be used. Separate sludge wells, into which sludge is deposited from the sludge hoppers and from which the sludge is pumped, are preferable to direct pump connections with the hoppers.

b. Circular tanks. Circular tank diameters range from 25 to 150 feet. Side-water depths are 7 feet as a minimum, and tank floors are deeper at the center. Flocculator-clarifiers, gaining wide acceptance in recent years, require much greater depths to accommodate sludge collection mechanisms. Adjustable overflow weirs (V-notch type) will extend around the entire periphery of the tank. Scum baffles, extending down to 6 inches below water surface, will be provided ahead of the overflow weir; and the distance between scum collection troughs will not exceed 75 feet along the periphery of the clarifier. A circular sludge-removal mechanism with peripheral speeds of 5 to 8 feet per minute will be provided for sludge collection at the center of the tank. Figure 11-4 illustrates a typical circular clairfier.

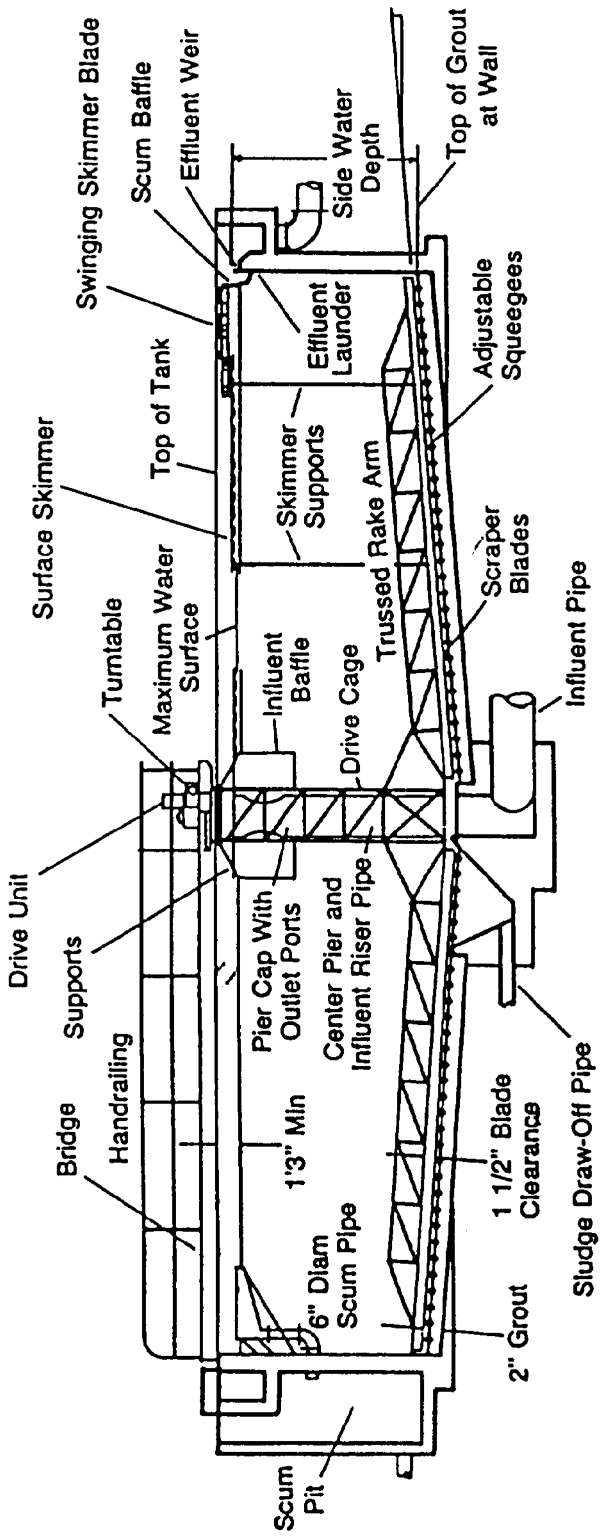

Figure 11-4. Typical circular primary sedimentation tank.

c. Typical design. Example C-3 illustrates a typical clarifier design.

11-4. Chemical precipitation.

Chemical treatment of wastewater may be advantageous when the following conditions exist:

— Wastewater flow and strength are intermittent and vary greatly;
— Space available for additional facilities is limited;
— Industrial waste that would interfere with biological treatment is present;
— The plant is overloaded;
— Plant odor is a problem;
— Phosphorus removal is desired; and
— Biological treatment processes are avoided.

Experience has shown that adding alum, iron or polyelectrolyte at either the primary or secondary clarifier is effective in increasing pollutant removal efficiencies. Lime addition is also effective if the effluent pH is adjusted (by recarbonation or acid addition) to acceptable limits for the subsequent treatment process or for final disposal. Jar tests will be made to determine optimum coagulants and dosages. Pilot studies should be made before selecting a coagulant.

a. Chemical used. The EPA **Process Design Manual for Suspended Solids Removal** provides criteria for the application of the chemistry and the use of the chemical precipitants discussed. Sample problem number C—4 illustrates the calculation of sludge volume resulting from chemical precipitation.

(1) **Aluminum salts**. Alum (hydrated aluminum sulfate) is the most widely used aluminum salt. It is effective in many wastewater applications but the precipitate sludge is difficult to dewater. The primary use of aluminum salts is for the removal of suspended solids and phosphorus. When alum is used, clarifier overflow rates will not exceed 600 gallons per day per square foot.

(2) **Iron salts.** Experience has shown that ferric salts are better coagulants than ferrous salts. Both ferrous and ferric salts are effective in the removal of suspended solids and phosphorous, but iron hydroxide carryover in the effluent can affect the effluent quality.

(3) **Lime.** Lime addition will improve grit separation, suspended solids removal, phosphorus removal, and oil and grease removal, as well as reduce odors from dried sludge. Dosage of lime equal to the suspended solids in wastewater is a common practice.

(4) **Polyelectrolytes.** These are used frequently, by themselves and in conjunction with other coagulant aids, to improve the solids-removal performance of sedimentation units. Their use should be based on jar test results and be reconfirmed by results in situ. They are more expensive on a unit-weight basis than the other chemicals in general use, but the required dosage is much lower. Polyelectrolytes—high molecular weight, water-soluble polymers classified as cationic, anionic, and nonionic—are highly ionized proprietary compounds. The cationic polymers are positively charged and will neutralize the negative surface charges on suspended particles, thus permitting agglomeration. Anionic (negatively charged) and nonionic (no charge) polyelectrolytes function as flocculants and must be used with a cationic material. The use of polyelectrolytes has been justified on the basis of improved water quality rather than cost savings. They can also permit higher flow rates through existing equipment.

b. Equipment for chemical precipitation. The following brief discussion on basic equipment required for chemical precipitation is useful for the design of such systems.

(1) **Mixing tanks**. The method for mixing wastewater and the chemical will be a flash mixing device in a mixing tank designed for 2 minutes detention time. The propeller will be specified so as to provide for the anticipated maximum flow in the mixing tank.

(2) **Flocculation**. Design criteria for air and mechanical flocculators are given in paragraph 10-6. Flocculation tanks will be designed for a detention time of 30 minutes.

(3) **Settling tanks**. The settling tanks involved in chemical treatment of wastewater will be designed for a minimum 2 hours detention time or the applicable maximum overflow rate stipulated in table 11-3.

Table 11-3.

Clarifier overflow design rates (gpd/sq ft)

Characteristic Waste	Clarifier Hydraulic Overflow Rate [1] [2] [3]	
	Primary Unit	Secondary Unit [4]
Raw Sewage	800	
Biologically Treated Waste		
Trickling Filter		600
Activated Sludge		700
Extended Aeration		600
Chemically Treated Waste[5]		
Alum Addition		500
Lime Addition		1,000
Iron Salts		800
Sludge Collection[6]		

[1]Seasonal temperatures exert a significant influence on basin performance. Allowance shall be made to the design factors shown in the table to compensate for the temperature. Ten State standards recommend an overflow rate of 600 gpd/sq ft or less for plants having a design flow of less than 1 mgd, but allow higher rates for larger plants.

[2]See design guidelines in paragraph 11-4 for guidance on use of circular versus rectangular tanks.

[3]Scum skimming to be provided on all settling tanks except in tertiary treatment. For secondary tanks in plants with primary settling, return skimmings to plant influent or wet well ahead of primary tanks. Use continuous gravity return if possible. If pumping is necessary, provide suction well at settling tank to receive discharge from skimming mechanism. Include provision for dilution of scum in well. For other applications, discharge scum to decanting-type containers in which it can be hauled to disposal.

[4]The most critical link in the operation of small plants (less than 1 mgd) is the secondary tank(s). The reason for this is inadequate solids separation at peak dry weather flows. Overflow rates are normally based on average design flows and carryover of suspended material occurs at higher flows. Effluent criteria now limit suspended solids concentrations in the treated wastewaters discharges; therefore, in small plants overflow rates used in design should take into account the peak dry-weather flow. Additionally, special attention should be given the design of the solids removal facilities if problems of rising sludge are to be avoided. A vacuum-operated underflow removal system or screw conveyors should be used to return the sludge on activated sludge processes.

[5]EPA Technology Transfer Series Manuals recommend a limitation of 500 gpd/sp ft.

[6]Circular tanks will be provided with plow-type sludge-removal mechanisms with peripheral speeds of 5 to 8 fpm with sludge collection at the center of the tank. Suction-type sludge withdrawal mechanisms may be used for secondary biological sludge if primary settling is provided ahead of the secondary treatment with sludge-collection mechanisms consisting of endless conveyor chains with cross pieces of tank. Linear conveyor speeds of 2-3 fpm are common, with speeds of 1 fpm for activated sludge. Separate slugde wells, into which sludge is deposited from sludge hoppers and from which the sludge is pumped, are preferred to direct pump connections with the hoppers.

11-5. Imhoff tanks.

Imhoff tanks provide removal of settleable solids and the anaerobic digestion of these solids in the same unit. They are two-level structures (fig 6-9) which allow the solids to settle out in the upper level. The settled solids then fall through slots into the lower level where they undergo digestion. The gas produced during digestion escapes through the vent areas along the sides of the upper level. A more detailed discussion of Imhoff tanks is included in paragraph 6-6. A two-compartment Imhoff tank is illustrated in figure 6-10. The upper level will be designed for a surface overflow rate of 600 gallons per day per square foot and a retention period of 3 hours at the average daily flow rate. The bottom of the lower digestion zone has sides which are sloped 1.4 vertical to 1.0 horizontal. The slot, which allows the solids to flow from the upper level to the lower level, is a 6-inch opening. An Imhoff tank can be designed so that a single digestion compartment can receive settled solids from multiple settling compartments. The digestion compartment should be designed to provide storage for 6 months' accumulation of sludge.

11-6. Sludge characteristics.

Table 11-4 represents typical characteristics of domestic sewage sludge.

Table 11-4. Typical characteristics of domestic sewage sludge.

Origin of Sludge	Solids Content of Wet Sludge[1] percent	Dry Solids[2] lb/day/capita
Primary Settling Tank	6	0.12
Trickling Filter Secondary	4	0.04
Mixed Primary and Trickling Filter Secondary	5	0.16
High Rate Activated Sludge Secondary	2.5-5	0.06
Mixed Primary and High Rate Activated Sludge Secondary	5	0.18
Conventional Activated Sludge Secondary	0.5-1	0.07
Mixed Primary and Conventional Activated Sludge Secondary	2-3	0.19
Extended Aeration Secondary	2	0.02

[1]Values based on removal efficiencies of well-operated treatment processes.

[2]Average 24-hr values. To estimate maximum 24-hr values, multiply given values by ratio of maximum 24-hr flow to average 24-hr flow.